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The Navy Distributed Engineering Plant – Value Added for Fleet

Jeffrey H. McConnell

ABSTRACT

The Navy's Distributed Engineering Plant (DEP) was rapidly established in 1998 to address critical Fleet interoperability issues. The primary mission of the DEP and its associated testing processes is to characterize the interoperability of each deploying Battle Group and provide this information to the Battle Group staff along with the acquisition community. The value of the DEP for this primary mission has been proven over the past three years while also establishing new DEP roles and capabilities. For instance, in fiscal year 2001 the DEP team has established new initiatives to help program managers find and resolve problems earlier in the acquisition cycle. As an example, the Cooperative Engagement Capability (CEC) program is now the second largest DEP user after the core mission of Battle Group interoperability testing. In addition, processes and tools have recently been established that enable the DEP to measure the performance of each Battle Group as a total system. This paper will provide a brief review of the history and capabilities of the DEP with a primary focus on the value added of the DEP, new initiatives and the outlook for the future.

INTRODUCTION

The best way to understand the DEP is to understand the interoperability crisis that drove its initial inception and ongoing evolution. This understanding will explain why the DEP was built, why it was built rapidly and why it is utilized in specific ways to support the Fleet on a daily basis.

Examples of documented Fleet interoperability failures are far too numerous to discuss in this paper. However, one well-documented example was recorded at the All-Service Combat Identification Evaluation Test in 1997 (ASCIET 97). This event occurred on the coast of Mississippi and brought together many Joint service systems including an Army Patriot battery, Air Force AWACS and a Navy AEGIS Cruiser off the coast. In many ways this could be viewed as a highly tuned, highly optimized environment in which the best systems were deployed and tuned by operators and engineers. In a very graphic demonstration of interoperability problems, a single aircraft flew through the ASCIET 97 operational area, but the LINK-16 network indicated three different tracks, three different track identities (unknown, friend and hostile) and three track numbers being shared for that one aircraft. Once again, for a highly tuned, Joint services environment, this was the best picture available on a LINK-16 network at the time.

There were many other problems that drove the interoperability crisis. The rapid evolution, severity and impact of these problems has 'snowballed' over many decades as the Navy rapidly added more and more interoperability functionality, such as LINK-11, LINK-16 and the CEC network, to the Fleet's combat systems. In 1998 this interoperability crisis, along with problems arising from the introduction of Commercial-Off-the-Shelf (COTS) technology, kept the AEGIS cruisers USS HUE CITY (CG-66) and USS VICKSBURG (CG-69) from deploying with their Battle Group.

These problems and many other frustrations in the Fleet led to the transmission of a Fleet message from the Commander-in-Chief Atlantic Fleet (CINCLANTFLT) to the Chief of Naval Operations (CNO) that said in part,

> "Resource sponsors, the PEOs and SYSCOM structure need to know that despite great efforts by dedicated professionals, they have failed to deliver integrated war fighting capability to our Battle Groups."

The CNO immediately responded with CNO message 021648Z_MAY98 which established Commander Naval Sea Systems

Command (NAVSEA) as the authority for resolving Fleet interoperability issues. NAVSEA-53 was assigned primary responsibility for addressing all issues required to resolve these interoperability problems.

Initial Solutions

In 1998 NAVSEA-53 rapidly initiated a variety of corrective solutions to address the interoperability problems of the Fleet. Many of these solutions had been conceived prior to 1998 and even partially prototyped in some cases but all were rapidly implemented due to the criticality of the situation.

The Navy Distributed Engineering Plant (DEP) and the Battle Force Interoperability Test (BFIT) were two important solutions that were established in response to this crisis. The DEP is a high-fidelity, shore-based Battle Group testbed. It is established by linking together dispersed combat system sites around the United States. When activated, the DEP network replicates an underway Navy Battle Group in a controlled and repeatable test environment. This networking is accomplished by utilizing the basic asynchronous transfer mode (ATM) networking technology that is the backbone of the Internet today. A key enabling component of the DEP is the KG-75 network encryption device developed by the National Security Agency. The KG-75 encrypts network information for transmission across public telephone networks without fear of compromise. The dynamic capability of the KG-75 provides an extraordinary amount of flexibility for deployment and management of the DEP network around the country and throughout the world.

As with any tool, the DEP is of little use if there is not a team capable of utilizing it to test the deploying Battle Groups. The BFIT is the battery of tests developed and executed by the BFIT test team to test the interoperability of every deploying Battlegroup. The BFIT utilizes the DEP as the high-fidelity tool to test every Battle Group, characterize its interoperability and report the results to the deploying Battle Group command staff. Discussion will begin with the DEP and the BFIT and then branch into other ways that the DEP is being utilized.

A Brief History of the DEP/BFIT

This paper will not go into great detail regarding the history of the DEP or how it conceptually functions. Readers may consult several sources for this background information including an article titled "The Navy Distributed Engineering Plant" published in the May/June 2000 edition of Surface Warfare Magazine. The body of that same article is available for download from the DEP website at http://www.nswc.navy.mil/dep.

In the Spring of 1998, in response to the CNO message 021648Z_MAY98, NAVSEA-53 stood up a task force to investigate various aspects of interoperability resolution. A primary focus of the task force was to investigate the possibility of federating land based combat system sites to form a shore-based Battle Group testbed. The task force met for six weeks in Washington D.C. and reported in June 1998 that the DEP concept was "technically feasible but would be organizationally difficult".

Figure I – The DEP Alliance

LABORATORY	LOCATION	COMMAND
Surface Warfare Center - Dahlgren Undersea Warfare Center Integrated Combat System Test Facility Surface Warfare Center – Port Hueneme Surface Warfare Center – Dam Neck Warfare Assessment Station Aegis Training and Readiness Center Surface Combatant Systems Center	Dahlgren, VA Newport, RI San Diego, CA Oxnard, CA Dam Neck, VA Corona, CA Dahlgren, VA Wallops Island, VA	Naval Sea Systems Command
Naval Air Warfare Center/AD Naval Air Warfare Center/WD	Patuxent River, MD China Lake, CA	Naval Air Systems Command
SSC – San Diego SSC – Charleston	San Diego, CA Charleston, SC	Space and Naval Warfare Systems Command (SSC)
Naval Research Laboratory	Arlington, VA	Office of Naval Research
The Applied Physics Laboratory	Laurel, MD	Johns Hopkins University

Shortly after the delivery of the task force report an Alliance of Navy laboratories was formed to develop a proposal to establish the DEP and BFIT for NAVSEA. The DEP Alliance, as it is called, consisted of 14 laboratories as depicted in Figure I. 12 of the laboratories were from the three Navy systems commands (NAVSEA, NAVAIR and SPAWAR) along with the Naval Research Lab and the Applied Physics Laboratory of the Johns Hopkins University. The DEP Alliance met all through the summer of 1998 and developed a detailed proposal that described all of the resources and talent that would be required to establish both the DEP and the BFIT team. That proposal was finalized and presented to a Flag review board on September 18, 1998. The board endorsed the idea and tasked the Alliance to establish the DEP and BFIT in four months in order to be ready to test the John F. Kennedy (JFK) Battle Group in time for her deployment.

The DEP was established by the DEP Alliance in that four month period and the JFK BFIT commenced on January 20, 1999. Results found in the BFIT testing correlated very well with problems seen at sea and detailed information was provided to the JFK Battle Group staff. Over the period of one year through January 26, 2000 the DEP team executed four BFITs covering five total Battle Groups (the last BFIT combined two very similar Battle Group configurations into one test). As of the fall of 2001 the DEP has executed 9 BFITs covering a total of 14 deployed Battle Groups.

DEP VALUE-ADDED

The balance of this discussion will focus on the value-added and contributions provided to the Fleet. The value-added provided by the DEP is presented in four sections: 1) Battle Group Deployment; 2) Problem Resolution; 3) Battle Group Capability Development and 4) Battle Group Performance Measurement.

DEP Value-Added: Battle Group Deployment

Testing each deploying Battle Group prior to deployment is the primary mission of the DEP as required in the Navy's Battle Group deployment preparation instruction (CINCLANTFLT/ CINCPACFLT Instruction 4720.3A).

To clarify and distinguish a previous point, the DEP is a massive, distributed tool that emulates a Battle Group and the BFIT is a specific test event (composed of plans, procedures, teams and processes) that is executed for each deploying Battle Group. Together since 1998 the DEP/BFIT team has uncovered numerous interoperability problems and has been the stimulus for initiation of several new programs to further enhance Fleet combat readiness. These new programs will be discussed in more detail in later sections.

One way of visualizing the BFIT is as a staircase with each step building on the previous step. At the start of a BFIT, testing begins by establishing and testing simple Battle Group connectivity. Then, overall complexity is steadily increased over a 5-week period. For example, the BFIT begins with one LINK-11 network, adds LINK-16 and then CEC. BFIT concludes with all communications networks operating simultaneously. The BFIT team tests the total Battle Group in its planned deployment configuration including the specific OPTASK LINK requirements and Identification supplement for the Battle Group's deployment theater.

Since the commissioning of the DEP, the complexity and productivity of the BFIT testing has grown significantly. For example, the first JFK BFIT was very comprehensive and accurate but the following BFIT for the Eisenhower Battle Group was far more complex and difficult with the addition of CEC, Global Command and Controls System-Maritime (GCCS-M) and other improvements. The BFIT testing has now come full circle, with the completion of the second JFK BFIT in the summer of 2001.

In the summer of 2001 the JFK Battle Group underwent DEP testing for the second time. Several new innovations were implemented. For the first time, the Surface Warfare Development Group (SWDG) joined with the BFIT team for specialized testing. SWDG was responsible for developing a Tactical Memo (TACMEMO) to support the Operational Evaluation (OPEVAL) of CEC on the JFK Battle Group in May of 2001. However, this TACMEMO could not support the JFK deployment several months after OPEVAL since many configuration details such as the CEC-capable E-2C would not be included in the deployment configuration. SWDG had to rapidly strip the OPEVAL TACMEMO down and rebuild it into a deployment TACMEMO. This did not leave any time in the pre-deployment schedule for SWDG to validate the new deployment TACMEMO prior to turning it over to the Fleet. The BFIT teams set aside two nights during the JFK BFIT for SWDG testing of the TACMEMO. The BFIT test team provided the expertise to write the test procedures and execute the test. The SWDG team was also able to verify and improve many aspects of the final TACMEMO and the collaboration was very successful and will greatly benefit the Fleet.

Another innovation implemented in the JFK BFIT was the dedication of two days of testing for the collection of Battle Force Interoperability Requirements (BFIR) metrics data. The BFIR metrics, processes and results will be described in more detail later in the fourth value-added module.

BFIR metrics had been collected in previous DEP events but the JFK BFIT provided dedicated test days in order to prove the value of measuring the performance of each Battle Group prior to deployment and in order to establish a baseline for comparison to upcoming Battle Groups. BFIR data collection events will be conducted in the DEP for all deploying Battle Groups. This will provide a common baseline of performance information across all Battle Groups, valuable insights and understanding to each deploying Battle Group staff and comparative metrics for the developmental community.

BFIT Products

The primary product of the BFIT for all deploying Battle Groups is the Data Management and Analysis Report (DMAR). This document captures all the test results of a BFIT including what was tested, how it was tested and all results for the Battle Group. An important sub-product coming out of the DMAR is input data for the Battle Group Capabilities and Limitations (Caps and Lims) document. This document, produced by NAVSEA/Port Hueneme, captures the platform level Caps and Lims of each platform as documented by the platform managers. With the advent of the BFIT, this document also captures the Caps and Lims of the Battle Group as a system. The BFIT team also provides comments to the techniques and procedures to be employed by the Battle Group staff as well as comments on the OPTASK and other initial setup procedures.

Trouble Reports (TRs) documented during the BFIT are submitted to and stored in a NAVSEA-53H central database and are provided to the Software Support Activities (SSAs) and program offices responsible for the resolution of these problems. This collection of information into a single repository has proven invaluable in uncovering trends that identify functional failure areas common to all Battle Groups as well as for measuring and documenting improvement between Battle Groups. This information in turn has driven problem resolution initiatives that will be discussed in the next value-added module.

BFIT As a Battle Group System Integration Milestone

Another unique aspect of the BFIT is the concept of Battle Group system integration and debugging. This concept is not usually documented or discussed but rapidly becomes apparent to those familiar with system development.

Prior to the existence of the DEP and BFIT process, there was a structured, six-month pre-deployment readiness process for each deploying Battle Group. The 'Achilles heel' of this process was that the first time the Battle Group came together as a total warfighting system was during the Battle Group System Integration Test (BGSIT). During BGSIT the ships and aircraft of the Battle Group first worked together, at sea, as a team, for integration, training and workups. At a more fundamental level, this meant the Battle Group Sailors were executing the functions of system integration and system debug instead of performing their intended at-sea function... operational training.

With the advent of the DEP and NAVSEA's new 30-month deployment preparation process (the "D-30" or 'deployment-minus-30 months' process as documented in Instruction 4720.3A), the DEP is now utilized to exercise a large portion of the Battle Group combat systems ashore during a BFIT prior to the Battle Group coming together at sea.

Even though the BFIT is executed to specifically characterize the interoperability of each Battle Group, the DEP tool and BFIT process have shifted a large portion of the Battle Group system integration and debug process back ashore where it belongs. An accredited replica of each Battle Group's combat systems hardware and computer programs now spend 5 weeks (15 eight-hour periods) in a highly controlled environment as the BFIT team executes this fundamental systems integration activity. Valuable and much more expensive BG underway time is now much more focused on underway operational training. Problems and work-arounds are reported to the Fleet. Now, Fleet Sailors go to sea and train to fight instead of finding and resolving combat system interoperability problems.

Credibility

There are many different ways to measure "Value-Added". The most desirable method is direct feedback from the customer. In this case the Fleet, as the customer, is seeing the value of the DEP/BFIT program ashore. This value-added is and has been documented in many messages from the Atlantic and Pacific Fleet Commanders. The DEP and BFIT is working. There is now documented evidence that the Fleet is spending a significantly higher percentage of the BGSIT event training vice debugging interoperability failures within the Battle Group.

DEP Value-Added: Problem Resolution

The second DEP value-added module takes a look at Battle Group problem resolution. Shortly after the DEP stood up, questions arose as to how the DEP could be employed to resolve the interoperability problems that were being found. The conventional answer was to 'pass the buck' to the platform program managers and their SSAs who were responsible. However, DEP personnel knew the DEP could play a large part in the problem resolution process and wanted to be a part of the engineering of solutions for the Fleet's combat system interoperability failures.

In the summer of 2000 the DEP team proposed a multi-pronged approach to NAVSEA-53 for the fiscal year 2001 program. First, the DEP teams would continue to test each deploying Battlegroup as mandated by Commander NAVSEA and the joint-CINCLANTFLT/CINPACFLT instruction 4720.3A. This is and continues to be the primary mission of the DEP. At the same time, the DEP team would undertake initiatives to help provide "near-term" solutions as well as "long-term" solutions to the Fleet's combat systems interoperability problems. This approach was approved by NAVSEA-53, has been implemented and has been proven very successful.

Interoperability System Engineering Test (ISET)

The ISET or Interoperability System Engineering Test executed in the DEP examines "root cause" of interoperability problems discovered during prior BGITS conducted in the DEP. The ground rules for an ISET are:

1) Focus on high priority Trouble Reports (TRs) with a high severity and high probability of occurrence.

2) Focus further on Frequent Offenders or problems that have plagued the Fleet for many years.

3) These TRs must have a high probability of re-occurrence. Essentially, if a problem appeared one time on the phosphor of a screen and disappeared – to never be seen again - no time would be devoted to checking into it. However, if a problem has been seen often, it is worthwhile to commit Battle Group system test assets to the resolution of that problem.

4) These problems must have a high probability of successful implementation. This means that the DEP team would focus only on problems that were in active combat system baselines and were not slated for resolution in the newest software upgrade being developed. Therefore, newly discovered and some lingering problems have a high probability of being fixed by the program SSAs. Many programs fall into this category including ACDS Block 0 carrier combat system that will be in the Fleet for many years to come. On the other hand, if a program/platform is in "caretaker" status - no money is available to fix problems or upgrade the system - there is little value in drilling down to find solutions.

The ISET Process

The key to making the ISET process work was partnering with the respective SSAs that are responsible for the primary combat systems involved in the ISETs. The DEP network and infrastructure were provided as a Battle Group tool with the DEP team, SSA engineers and programmers manning the combat system consoles. During the ISET, the DEP is used to federate a small Battle Group and the Battle Group is tested in this configuration for several nights. In contrast to BFIT testing, this is more of an iterative testing process performed with an engineering/tester approach – find a problem, back up, retest, try different parameters and in essence help the engineers and programmers to isolate faults to the computer code level.

The ISET execution cycle consists of four major steps. ISET test #1 validates the ISET process. ISET test #2 actually drills down to discover the root cause of the target problem list. ISET test #3 is executed to re-test any aspects of the ISET test #2 findings that need amplification. Between ISET test #2 and ISET test #4 the SSAs implement fixes for problems found earlier. ISET test #4 validates the solutions. The ISET fix cycle is timed to occur within the normal development cycle of the individual platform processes.

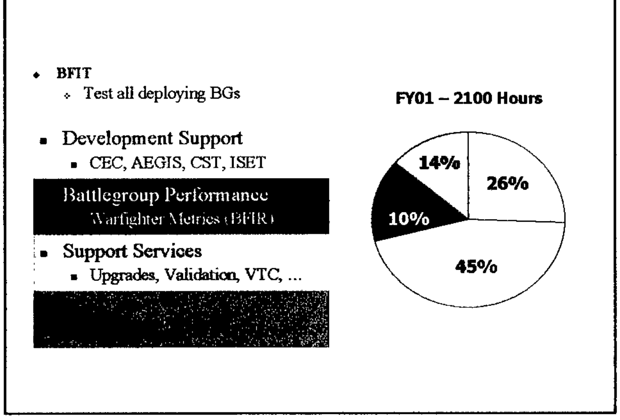
ISET tests #1, #2 and #3 were executed within FY2001. Due to resource limitations, ISET #4 is planned to occur in FY2002 leading to final validation of the problem resolutions and the ISET process in general. Preliminary findings and indications have shown the ISET concept to be a very powerful tool for Battle Group system problem resolution.

DEP Value Added: Battle Group Capability Development

The third DEP Value Added module addresses support to Battle Group capability development. This is an initiative in which the DEP is being utilized to assist the acquisition community in building better systems before they commence the D-30 process and ultimately deploy with a Battle Group.

Figure II shows the level of DEP support now being provided to the acquisition community. The metric on this pie chart is the number of hours that the DEP ATM network was actually utilized by various programs. The DEP ATM network is actually available 365 days a year, 24 hours a day and the DEP utilized that network a total of 2100 hours in FY2001.

Figure II – DEP Utilization



Although BFIT is the primary mission of the DEP, a close examination of Figure II shows that the DEP was actually used more in FY 2001 to support developmental programs. Support to BFIT testing took 26% of the DEP ATM time in FY 2001 as compared to 45% for supporting developmental programs. The data in Figure II includes actual test execution time as well as bulk data transfers and other support services. Figure II also shows that the DEP supplied 10% of the ATM utilization to Battle Group performance measurement (to be discussed in more detail later), 5% to perform integration tasks as the Joint DEP (JDEP) sites were added to the DEP and 14% for plant validation, plant upgrades and maintenance.

The FY 2001 DEP utilization data clearly documents the DEP's growing and continued contribution to NAVSEA's systems development mission and documents the realization of another of the founding visions for the DEP ... specifically, to enable interoperability testing of new systems much earlier in their acquisition cycle in order to deliver interoperable systems to the Fleet the very first time they go to sea.

With NAVSEA's concurrence, DEP is now providing the ATM network and some test infrastructure to the developmental communities to enable them to provide a better product to the Fleet. In most cases these programs are paying for combat system site costs as well as the cost of manning those sites. Therefore there is little additional cost to NAVSEA-53 other than the sunk cost of the ATM bandwidth.

Primary users within the developmental community include the CEC program, the AEGIS program for multi-platform testing, the ISETs that were just described and Collaborative Systems Tests (CSTs) which will be described next.

Collaborative Systems Tests (CSTs)

The DEP again proved its worth and value added in the summer of FY 2001. The JFK Battle Group was working up again for its second deployment since the DEP was established. The Battle Group was scheduled to deploy this time with the USS HUE CITY and USS VICKSBURG AEGIS cruisers. Pre-deployment milestones were tightly compacted with CEC OPEVAL scheduled on the JFK Battle Group in May of FY2001 and the JFK BFIT scheduled just one month later. In response to the pressures related to this Battle Group, CSTs were proposed and approved as a risk mitigation step to help shepherd the JFK Battle Group through critical interoperability and operational testing milestones.

The philosophy of the CST was to preview the interoperability performance of a Battle Group earlier in the D-30 cycle in order to discover and correct interoperability problems during the developmental cycle. This was achieved by establishing a mini Battle Group over the DEP ATM network, using early developmental system computer program loads and manning the platform consoles with SSA engineers and programmers. This enabled the engineers and programmers to see how their respective systems performed as a part of the Battle Group system. The hope was that problems seen by the platform development personnel could be fixed prior to the OPEVAL, the BFIT and the eventual Battle Group deployment.

Results are still under development for several platforms but one big success story comes from the first JFK CST event. During this event, four key problems were discovered with the FFG-7 class guided missile frigates and their Combat Direction System (CDS) computer programs. This system is essentially in caretaker status meaning no fixes will be implemented on this system. In this case however the CDS program manager approved resources to fix the four problems, generating the CDS Level 13, patch version 0004X that was ultimately tested in JFK BFIT and will deploy with the JFK Battle Group.

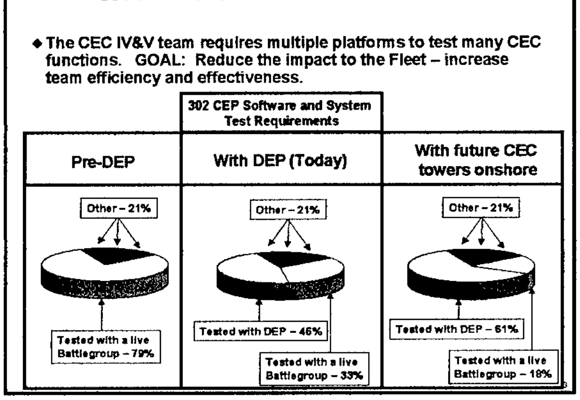
For years the FFG CDS has caused intolerable problems on the Battle Group LINK-11 network and relegated the FFGs to operate in LINK-11 "receive-only" mode. Bottom line ...

repairs stemming from the CST have enabled the JFK Battle Group to regain full utility of its FFG resources in two-way LINK-11 operations.

CEC Development

The CEC program has been another benefactor of the DEP's developmental support capability. Shortly after the DEP was established, the CEC program approached the DEP management team and began to use the DEP to test the CEC system. Prior to the DEP, CEC performed as much testing ashore as possible, performing CEC system integration and CEC-to-combat system integration at the land based combat system sites. However, as a multi-ship capability, the bulk of CEC testing had to be performed in a multi-ship environment. This required live testing on an underway Battle Group. Not only was this expensive for the Fleet Commanders to support but from an engineering perspective, it was also far from satisfactory. The live Battle Group as a 'testbed', albeit very high in fidelity, was very inefficient in terms of providing a "controlled and repeatable" environment necessary to foster "engineered" solutions.

Figure III – CEC Testing Improvements



As shown on the left-hand pie chart of Figure III, prior to the DEP the CEC IV&V team had to test 79% of 302 Cooperative Engagement Processor (CEP) requirements on the live Battle Group ships. With the advent of the DEP, the CEC IV&V team has rapidly become the DEPs' second largest user and is now able to test 46% of their requirements in the DEP leaving 33% to be tested on the live ships as shown in the middle pie chart.

The third pie chart is provided as an illustration of how DEP fidelity improvements provide an additional positive impact for the Fleet. The DEP has always incorporated the real CEP portion of CEC but never the Data Distribution System (DDS). The DDS contains over 200,000 lines of code and a significant amount of CEC functionality. This functionality and the behavior of the DDS network has been emulated in the DEP via the use of a Wrap-Around Simulation Program (WASP).

The CEC program is currently constructing several 400-foot towers on the East Coast. These towers have a real CEC antenna and the real DDS cabinet of the CEC system. Meanwhile, the DEP team along with the CEC team is evaluating how to employ the DEP ATM network to take land-based combat systems with their CEPs and 'connect' them to the DDS at the towers. This would effectively allow any shore-based combat system on the DEP to participate in a live CEC network (including, potentially, ships offshore). This would bring the live DDS, along with its 200,000 lines of code, into the DEP architecture and allow the CEC IV&V team to test an additional 15% of the CEC requirements ashore. CEC live Battle Group testing requirements are projected to be further reduced downward to 18%.

For the CEC program the benefits of using the DEP have proven to be very significant. The CEC program is now able to more rigorously test ashore, as a system, in a repeatable, controlled environment. This leads to the ability to deliver a better product to the Fleet while reducing the impacts to the Fleet schedule, training and quality of life.

DEP Value Added: Battle Group Performance

The ability to measure the performance of any system against a 'yardstick' is critical to any systems engineering function as it supports an acquisition program. The metrics provided indicate system capability, functionality, developmental progress and potential for system improvement and investment. This final discussion module takes a look at how the DEP is being utilized to measure the performance of the Battlegroup as a single system.

Establishing BFIR Metrics

The ability of the DEP to measure total Battle Group system performance is rooted in another program called the Battle Force Interoperability Requirements (BFIR) program. Sponsored by NAVSEA-53C, the BFIR program was established in the 1999/2000 timeframe to address questions arising from the CNO-N8 and Assistant Secretary of the Navy /Research, Development and Acquisition (ASN(RDA)) organizations with respect to Battle Group performance.

N8 was seeking methods to measure the performance and interoperability of Battle Groups as the systems and sub-systems of the Battle Group are acquired, deployed and upgraded. In a similar manner, ASN(RDA) was preparing to make LRIP #2 (Low Rate Initial Production), LRIP #4 and [eventually] Full Rate Production (FRP) decisions for the CEC program and needed Battle Group-level metrics that could demonstrate the value-added to the Fleet if the CEC system was to be procured and deployed. These metrics would be utilized to help make the upcoming milestone decisions.

NAVSEA-53C undertook the task of developing this detailed level of metrics and established the BFIR team. Working with N8 and ASN(RDA), the BFIR team described a high-level metric called Track Information Quality (TIQ). TIQ consists of 6 metrics that expand to 26 sub-metrics. The BFIR team worked to rapidly define all levels of this metric hierarchy and then began the work of developing a metrics collection methodology as well as the algorithms and tools needed to produce the sub-metrics and then roll-up the TIQ metric.

A primary goal of the BFIR team is to utilize the metrics developed and the measured values of those metrics to write a Battle Force Interoperability Capstone Requirements Document (BFI CRD). This CRD will help the Navy to specify the performance of the Battle Group as a system and provide requirements to develop towards in the future.

Track Information Quality

Before understanding how the BFIR/DEP relationship is adding value for the Fleet, TIQ and its application to Battle Group performance measurement must be understood.

TIQ is a rollup of many sub-metrics into an aggregate measure of Battle Group shared situational awareness. It describes the quality of information shared by all commanders within the Battlegroup with respect to a track. For purposes of this paper, all tracks are air tracks.

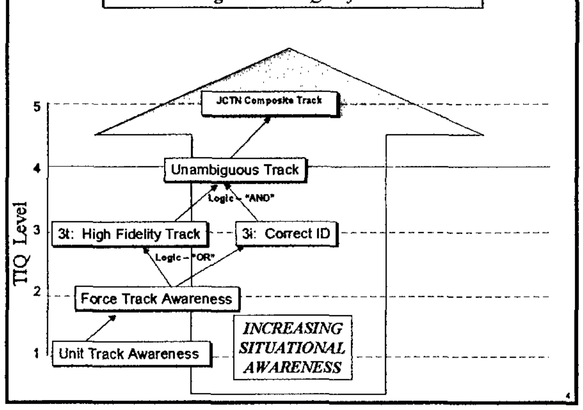


Figure IV – TIQ Defined

As shown in Figure IV, TIQ begins at level 1 which is described as "Unit Track Awareness". This level indicates that an aircraft or missile has entered the detection range of the Battle Group and a Battle Group ship or aircraft has developed a sensor track on that object. The detecting unit has not transmitted any track information onto the data LINKs.

Level 2 is called "Force Track Awareness". At this level, information about the track has been transmitted over a LINK and other Battle Group commanders are aware of the track. It does not mean that this is a high quality track with good positional and identification information.

Level 3 is actually made up of two branches, 3i and 3t. 3t is referred to as a high-fidelity track. This indicates that high quality kinematic information is being shared on the LINKs for this track. Essentially its position and velocity are correctly measured and have been shared on the LINKs. 3t also means that there are no dual tracks or multi-track information on the LINKs. 3i on the other hand means that the identification (ID) has been correctly resolved and accurately reported to all commanders in the Battle Group.

Level 4 is defined as the simultaneous achievement and maintenance of both 3i and 3t. In other words, at level 4, the Battle Group has achieved, and fully shares an unambiguous track for the object. This means that all Battle Group commanders share the same picture for that track with accurate positional and ID information available on all combat systems. Fundamentally it means that any Battle Group commander can shoot a TIQ level 4 track with confidence that he is hitting the right target and is not shooting blue or white forces.

Level 5 is a level that is being looked at for the future. It is being reserved in case the current Navy CEC or future Joint Composite Tracking Network (JCTN) can provide unique contributions to TIQ. At a fundamental level, the sensor netting provided by CEC provides a faster determination of 3t. The composite ID capability of CEC enables a more rapid resolution of 3i. Rapid resolution of 3i and 3t means an earlier achievement of TIQ Level 4. The real question for Level 5 is whether CEC/JCTN provides any unique information, other than faster resolution of 3i and 3t, that could enhance Battle Group situational awareness or engagement capability.

It should be noted that the TIQ levels are not available to the Battle Group commanders as they are fighting. TIQ is determined by comparing the Battlegroup perception of kinematics and ID as it is shared, in relation to absolute truth. In other words, TIQ can only be known when the shared information is compared to ground truth information. This ground truth is available in the DEP via the recorded Distributed Interactive Simulation (DIS) position information for the track. Ground truth is available in live exercises by recording GPS positional information for each track under evaluation.

A very broad scope of information is inherently included into the TIQ levels. TIQ includes the inputs of sensor performance, system performance (meaning the performance of every computer and computer program on each combatant), the interoperability of all units, the performance of the operators involved as well as the impact of rules of engagement (ROE) and tactics, techniques and procedures (TTPs) that govern their decisions. This opens the possibility to measure the contribution of individual systems/subsystems and processes as they impact the overall performance of the Battle Group system.

BFIR Data Extraction

The BFIR team, in addition to defining TIQ as a measure, also determined the means to collect the information that makes up TIQ. This consisted of identifying the key combat systems in a Battlegroup that contribute to TIQ and developing a common list of information that must be extracted from each combat system including track position, velocity and heading. The team set up these measures, data collection processes and the algorithms and utilities that could compare these measures to ground truth and develop the final TIQ values for any exercise.

DRM Scenarios

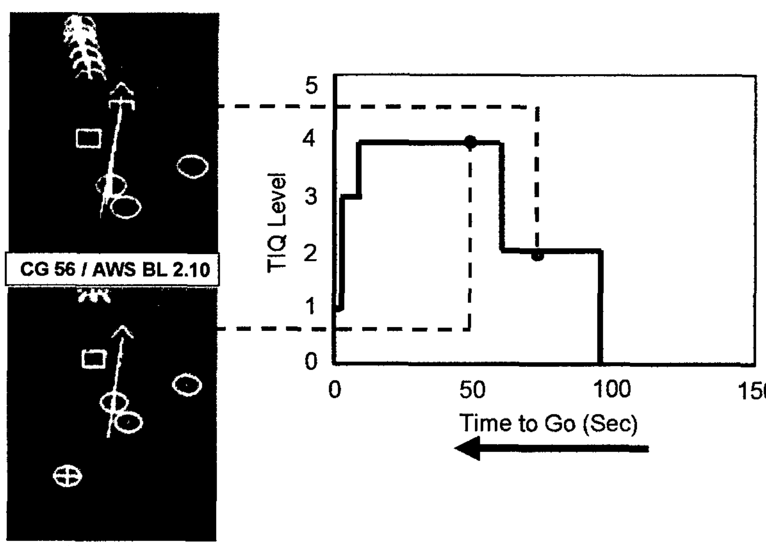
The BFIR team also established a set of baseline scenarios that stress the various levels of TIQ in an operationally significant setting. These scenarios were extracted from the Design Reference Missions (DRMs) that were recently developed as an operationally representative reference mission for analysis. The basic BFIR scenario places the carrier Battle Group off of a coastline. A commercial airway is represented over the landmass. Hostile aircraft mimicking commercial aircraft depart from the airway and launch sea-skimming missiles toward the carrier. In the most rigorous scenario, shore-based Transporter Erector Launchers (TELs) also launch sea-skimming missiles toward the carrier for an ultimate raid size of 8 inbound targets.

These DRM scenarios have been converted into DIS scenarios for execution in the DEP and are also the basis for the live events that have been executed to measure live Battle Group performance.

BFIR Products

One of the primary products of a BFIR analysis is the TIQ plot as seen on the right-hand side of Figure V. The horizontal axis is defined as time-to-go (in seconds) to the high-value target (the carrier in this case). This axis is read from right to left as the target flies toward the high-value target. The vertical axis is TIQ starting with zero at the origin and progressing toward level 5. Overall, this plot describes the total situation awareness held by the Battle Group combatants as the target flies inbound and the Battle Group units work to resolve the position and ID of one target.

Figure V – TIQ Example

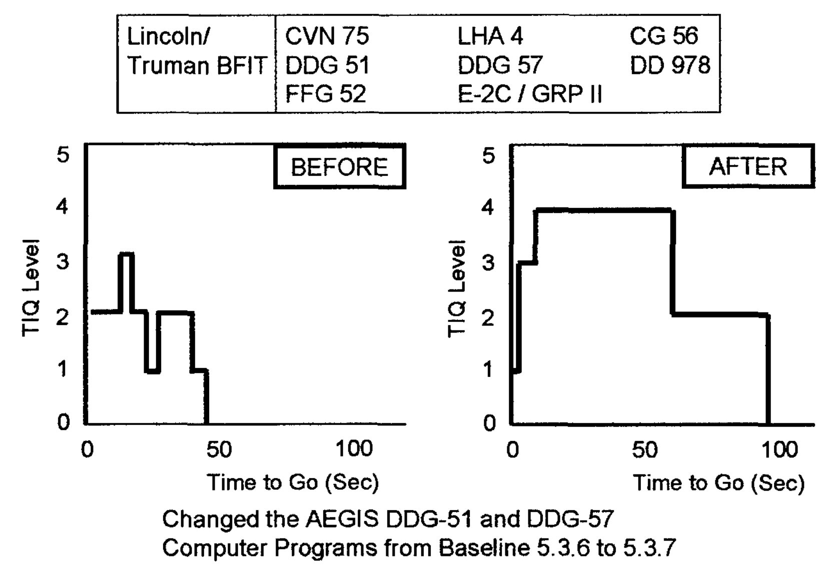


As shown in Figure V, the first example of measured TIQ is illustrated on the TIQ plot at about 90 seconds time-to-go. The plot indicates a dual track on the target as well as two IDs, hostile and unknown. In this case, neither 3i nor 3t have been achieved so the track is held at TIQ level 2. At 70 seconds time-to-go the Battle Group was able to resolve both 3i and 3t at the same time and the TIQ jumps to level 4. As seen on the displays at the lower left there is one track and one ID (hostile) being shared on all units and both the kinematics and ID are correct according to ground truth. The Battle Group was able to maintain level 4 all the way in to the carrier until one combat system had a problem measuring the speed of the target and the TIQ dropped to level 3i – identification was still held correctly but 3t was not maintained.

Lincoln/Truman BFIT

Now that we have established TIQ and understand how to interpret the TIQ levels a wealth of information is made available. The BFIR team is now writing the BFI CRD utilizing the understanding of TIQ to establish meaningful measures with meaningful values for performance thresholds and objectives. The ability to measure TIQ and all of the associated sub-metrics enables detailed analysis of the contributors and detractors that make up overall TIQ. The BFIR team can go back into the data and focus on a specific threat and how the Battle Group handled that threat as well as focus on the contributions of an individual unit within the Battle Group. Eventually this will help the acquisition community to implement improvements that will lead to overall Battle Group performance improvements.

Figure VI – Measured TIQ Improvement



The two plots shown graphically in Figure VI illustrate the insights provided by the TIQ measurements when they are exercised in the DEP. The left-hand plot shows the TIQ levels achieved for a single target flying toward the Lincoln Battlegroup during the Lincoln/Truman BFIT. The plot shows that the Battle Group did not achieve TIQ level 2 until 35 seconds time-to-go and was unstable even at that level. There was a brief jump to level 3t but the Battle Group never achieved level 4.

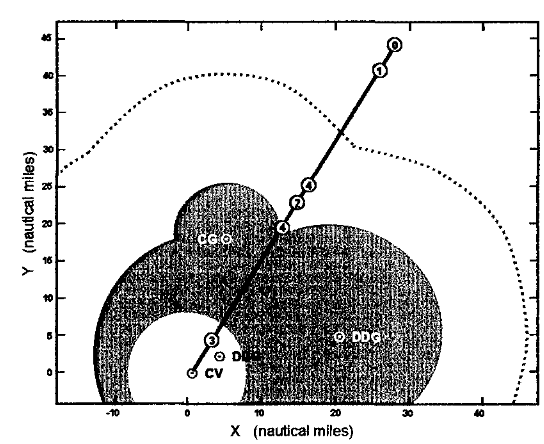
A primary contributor to this low TIQ performance was the AEGIS baseline 5.3.6 combat system installed in the DDG-57. Baseline 5.3.6 had many known performance and interoperability issues that were causing problems with the shared situational awareness of the Battle Group. The follow-on baseline 5.3.7 fixed these problems and has been a big improvement for the Fleet. The magnitude of the performance improvement can be seen in the right-hand plot. In this case, the baseline 5.3.6 computer programs were removed from the destroyer and the 5.3.7 system installed. The DIS scenario was replayed in the DEP and accurately repeated the entire scenario. The plot shows that the Battle Group achieved level 2 with about 90 seconds time-to-go and achieved a good level 4 at 70 seconds time-to-go. Level 4 was maintained for the remainder of the scenario except for a speed failure near the end.

Engineers as well as Fleet operators can now see graphic and detailed analytical differences between Battle Groups and components within Battle Groups. This level of analysis enables the engineering community to dissect a Battle Group and its components and derive improvements to capabilities that will improve overall Battle Group performance.

Impact to Force Protection – Air Defense Decision Point

On the plot shown in Figure VII, the distance to the carrier is plotted on the x and y axes with the threat inbound toward the carrier at the 0,0 point.

Figure VII – Weapons Engagement Zone Impacts



The AEGIS destroyers and cruiser are arrayed in a typical fashion with regard to the carrier. The TIQ level changes are denoted by the numbered circles along the threat axis. The plot also denotes with various colors the weapons engagement zones of the combatants. The Standard (area defense) missiles of the AEGIS platforms are depicted in dark gray. The self defense missiles (SeaSparrow) of the carrier come in to play with the light gray zone. Other weapons engagement zones including the F-14 Combat Air Patrol and the Carrier's Close In Weapons System (CIWS) are not depicted to improve clarity.

The potential engagement zone of each weapon is depicted by the outer, dashed arc of color versus the inner solid color region for each weapon. For example, the potential engagement zone of the Standard missiles is defined by the outer gray arcs and the actual engagement zones against this threat are defined by the inner solid gray circles. The difference between potential and actual engagement zones is determined by the TIQ level versus range. For instance, the TIQ level jumps briefly to level 4 at the first point on the chart but falls back to Level 2 shortly thereafter. When Level 4 is finally achieved and maintained, the actual performance of the Standard missiles is depicted for each of the AEGIS combatants. In essence, this inner zone of Level 4 is the only point at which the Battle Group commanders can commit Standard missiles and be confident that they are hitting the correct target.

This presentation of analysis results immediately opens questions for the Fleet and the acquisition community. These questions can rapidly and logically flow down in the following manner:

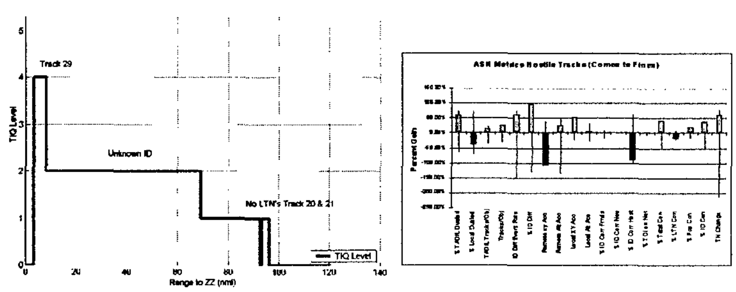
- How can we 'buy-back' the lost engagement capability of our area defense missiles?
  - In essence - how can we get to TIQ level 4 faster?
    - How do we achieve 3i faster?
      - Improve ID sensors/systems
      - Cooperative ID systems
      - Non-cooperative systems
      - Etc.
    - How do we achieve 3t faster?
      - Improve active sensors
      - Improve passive sensors
      - Multi-source, multi-spectral sensor integration
      - Improve support services (gridlock, correlation, etc.)
      - Sensor netting
      - Etc.

In essence, given a testbed and a yardstick, a good engineer can balance, improve and optimize a system for maximum capability. Through the DEP and the BFIR programs those tools are now available at the Battle Group system level and the potential for effective capability improvement is immense.

Live BGSIT experience

Figure VIII is included to show that the same BFIR capabilities demonstrated and utilized in the DEP have been utilized many times in the live environment.

Figure VIII – Live BGSIT Measurements



The information depicted is from a recent live BGSIT event. During this event, the Battle Group and the aggressor aircraft tried to emulate the DRM scenarios as closely as possible. The BFIR team collected the appropriate data points and ran the data through the BFIR algorithms. The BFIR team generated the standard TIQ/time-to-go charts as well as the chart to the right that breaks out the 26 sub-metrics and how well the Battle Group under test relates to a 'baseline' of those metrics.

The BFIR metrics have proven very useful during the Battle Group staff debrief meetings after the BGSIT exercise. The TIQ plots are very meaningful to the operators and have been useful for event reconstruction and overall evaluation of team performance. The left-hand plot in Figure VII alerted the Battle Group staff that simulated ROE and TTP were not being properly implemented by the operators within the Battle Group. In many cases with an aggressor inbound the operators were not elevating the simulated threats to hostile in a timely manner. The TIQ information provided tangible, timely information to help the Battle Group team debrief and plan for improved execution on subsequent days of the BGSIT.

BFIR/DEP Mutual Support

There is a very real synergy and mutual support between the DEP and BFIR programs. The DEP provides a precise, repeatable environment in which the BFIR metrics can be executed repeatedly. This enables the kind of what-if testing and incremental analysis that is essential to the development of new capabilities for the Fleet. At a more fundamental level, the DEP data extraction network assists the BFIR team by transferring megabytes of data and ground truth information from around the country to the BFIR analysts within minutes of a test execution.

In the other direction, the BFIR work has provided a powerful set of new metrics to be applied within DEP testing. The BFIR scenarios are now included in the basic set of tests run for every Battle Group with two nights of BFIT testing devoted to BFIR metrics collection for each Battle Group. These metrics will allow comparison of performance between Battle Groups as well as a measure of progress between Battle Groups. The eventual development of the BFI CRD may lead to a full set of Battle Group performance requirements that will enable full-spectrum certification of Battle Group capabilities.

CONCLUSION

Achieving Battle Group or Battle Force interoperability requires a multi-pronged approach driving toward a common systems engineering process. Today we have the D-30 process that dictates a disciplined Battle Group configuration management process with defined milestones, events and exit/entry criteria. The DEP is also in place and fully operational for the Anti-Air warfare mission. The DEP has made significant contributions by treating the Battle Group as a system and testing all components of the Battle Group in a rigorous, repeatable environment. In addition, as a Battle Group testbed, we are just beginning to realize the ability of the DEP to support system development programs as well as system acquisition decisions via performance analysis. Finally, the BFIR program is providing quantitative analysis of Battle Group performance. This information is critical to bounding the performance required of US Battle Groups via BFI CRD development as well as by measuring current and future performance of Battle Groups and Battle Group system components as they are acquired. Together, these three initiatives form a solid foundation for achieving Battle Groups that are greater than the sum of the capabilities of their individual ships and aircraft systems.

BIOGRAPHY

Jeffrey H. McConnell attended Geneva College and graduated cum laude with a Bachelor of Science in General Engineering in 1982. He began his career as a civil servant with the U.S. Navy at the Naval Air Test Center, Patuxent River, Maryland in 1982. Mr. McConnell transferred to the Naval Surface Warfare Center (NSWC), Dahlgren, Virginia in 1983 and immediately went to work on the Tomahawk program. In 1985 Mr. McConnell moved to the fledgling Vertical Launching

System (VLS) software development program. His duties ranged from VLS lead test engineer to VLS lead for tactical and support software development.

Mr. McConnell became the NSWC Deputy Program Manager for Theater Ballistic Missile Defense (TBMD) in 1993. He moved on to become the NSWC Deputy Program Manager for the Cooperative Engagement Capability (CEC) in 1996. In 1998 Mr. McConnell was asked to join the NAVSEA Task Force on Combat System Interoperability and made significant contributions to the establishment of the Navy Distributed Engineering Plant (DEP). In 1999 Mr. McConnell became the Deputy Technical Coordinator for the DEP.